

FORMALDEHYDE-FREE DUCT LINER

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation-in-part of the following copending United States patent applications: U.S. patent application Serial number 10/689,858, filed on October 22, 2003, U.S. patent application Serial number 09/946,476, filed on September 6, 2001, and U.S. patent application Serial number 10/766,052, filed on January 28, 2004, which are commonly assigned and hereby incorporated by reference.

[0002] This application is also related to U.S. Patent No. 6,673,280, issued January 6, 2004, and U.S. patent application Serial number _____, filed on February 18, 2004, for INORGANIC FIBER INSULATION MADE FROM GLASS FIBERS AND POLYMER BONDING FIBERS, which are also commonly assigned and hereby incorporated by reference.

FIELD OF THE INVENTION

[0003] The present invention relates to fiber insulation and, more particularly, to substantially formaldehyde-free duct liners comprising inorganic or organic fibers and, preferably, formaldehyde-free plastic-containing bonding fibers in which the plastic-containing bonding fibers are the binder material.

BACKGROUND OF THE INVENTION

[0004] Ducts and conduits are used to convey air in building heating, ventilation and air conditioning (HVAC) systems. In many applications, especially in commercial and industrial constructions, the ducts are lined with flexible thermal and acoustic insulating material. The lining enhances the thermal efficiency of the duct work and reduces noise associated with movement of air therethrough. Duct liners may comprise any suitable organic material or inorganic material, e.g., mineral fibers such as fiber glass insulation or the like. Typical fiber glass duct liners, for example, are constructed as fiber glass mats having densities of about 1.5 to 3 pounds per cubic foot (pcf) and thicknesses of about 0.5 to 2 inches.

[0005] To prevent fiber erosion due to air flow, the insulation may include a coating or a facing layer on its inner or “air stream” surface. The air stream surface of the insulation is the surface that conveys air through the duct and is opposite the surface that contacts the duct sheet metal in the final duct assembly. Examples of such duct liners are provided in United States Patent Nos. 3,861,425 and 4,101,700. Several insulation duct liners are marketed under the trade designations Toughgard® by CertainTeed Corp. of Valley Forge, PA, Aeroflex® and Aeromat® by Owens Corning Fiberglas Corp. of Toledo, OH, Permacote®, and Polycoustic™ by Johns Manville Corp. of Denver, CO.

[0006] As an alternative to coated duct liners, manufacturers such as CertainTeed Corp. and Knauf Fiber Glass GmbH offer duct liners having glass fiber insulation covered with a layer of non-woven facing material which defines the air stream surface of those products. The facing material produces a durable surface that protects the air duct from fiber erosion.

[0007] In traditional duct liners, phenolic powder resin binders are used to bond the fibers together. These resin binders, such as phenol-formaldehyde, generally contain formaldehyde. Although there is no health risk with the traditional fiber glass duct liners using formaldehyde-containing binders, formaldehyde at higher levels may cause skin irritation and sensitivity. In consideration of such concerns, manufacturers of insulation products have started to offer formaldehyde-free products to provide the consumers an alternative to the traditional insulation products including duct liners.

[0008] These currently existing formaldehyde-free insulation products use water soluble acrylic binders that are formaldehyde-free in place of the phenolic powder resin binders. Some examples of formaldehyde-free binders used in such applications can be found in United States Patent Nos. 5,932,665 and 6,331,350. However, because these acrylic binders are applied in aqueous form, they are generally more difficult to use in manufacturing process compared to binders in dry form. Thus, there is a need for formaldehyde-free duct liners fabricated with dry formaldehyde-free binders without compromising on the manufacturability and the performance characteristics of the duct liners.

SUMMARY OF THE INVENTION

[0009] According to an aspect of the present invention, substantially formaldehyde-free duct liners and the methods of making the duct liners are disclosed. The duct liners according to an embodiment of the present invention comprise at least one fiber component, that may be virgin textile glass fibers, blended with a non-liquid substantially formaldehyde-free binder bonding at least a portion of the fiber component to produce formaldehyde-free duct liners that have a substantially uniform density throughout their volume.

[0010] In an embodiment of the present invention, the non-liquid substantially formaldehyde-free binder is substantially the only binder material used in the duct liner.

[0011] In another embodiment of the present invention, the fiber component of the substantially formaldehyde-free duct liners may comprise textile glass fibers, rotary glass fibers, organic fibers, or natural fibers such as wood fibers, hemp fibers, cellulose fibers, etc. or a combination thereof. Preferably, these fibers are virgin fibers that have not been previously treated or otherwise processed with any formaldehyde-containing chemicals such as formaldehyde-containing binders. By employing one or more of these fibers in the formulation for the formaldehyde-free duct liners, it is possible to customize the final properties of the duct liners.

[0012] The non-liquid substantially formaldehyde-free binder may be plastic-containing bonding fibers, a powder binder, or a mixture thereof. The plastic-containing bonding fibers may be thermoplastic polymer fibers, thermo-setting polymer fibers prior to heating and/or curing, or combinations thereof. They may also be mono-component, bi-component or a combination thereof. The mono-component polymeric fibers are solid or tubular fibers of a single polymeric material. The bi-component polymeric fibers may be of the sheath-core construction wherein the sheath material has a lower melting point than the core material. The bi-component polymeric fibers may be of other constructions. For example, the two components may have side-by-side or segmented pie construction in cross section. Plastic coated inorganic fibers, such as thermoplastic sized or thermosetting plastic-coated glass fibers may also be used.

[0013] When plastic-containing bonding fibers are used as the non-liquid substantially formaldehyde-free binder, the fiber component and the plastic-containing

bonding fibers are uniformly blended and bonded together by a portion of the plastic of the plastic-containing bonding fibers.

[0014] Generally, a facing layer may be applied to at least one side of the fiber mat that forms the body of the duct liner. The facing layer is generally applied to the “air stream” surface of the duct liner. The facing layer is typically a non-woven scrim.

[0015] In addition to being substantially formaldehyde-free, the plastic-containing bonding fibers in general provide stronger adhesion between the duct liner’s fiber mat body and the facing layer because of the rooting effect of the plastic-containing bonding fibers. Rooting effect refers to the fact that many of the plastic-containing bonding fibers near the surface of the fiber mat that bonds to the facing layer extends into the bulk of the fiber mat. Because these bonding fibers are also bonded to the other fibers (glass fibers as well as other bonding fibers) within the fiber mat, analogous to tree roots in the ground, they securely bond the facing layer to the fiber mat. Furthermore, by using bi-component polymeric fibers, the plastic-containing bonding fibers may also provide reinforcement for the duct liner.

[0016] The powdered binders may be any suitable formaldehyde-free thermoplastic or thermosetting powdered binders such as thermoplastic or heat-curable thermosetting resin. The powdered binders may be used alone or in combination with the plastic-containing bonding fibers and blended with the fiber component of the duct liners.

[0017] The use of these formaldehyde-free binders allow the duct liner fabrication process to remain dry which is generally simpler than using the liquid acrylic binders as the formaldehyde-free binder. The process would consume less energy because there is no water to vaporize. The duct liner and/or the facing layer may be treated with anti-microbial agent to resist growth of fungi or bacteria.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] FIGURE 1 is a cross-sectional view of an exemplary embodiment of a duct liner according to an aspect of the present invention;

[0019] FIGURE 2 is a schematic illustration of an apparatus for forming the duct liner of the present invention;

[0020] FIGURE 3a-3c are detailed schematic illustrations of the bale openers of the apparatus of FIGURE 2;

[0021] FIGURE 4 is a detailed schematic illustration of another section of the apparatus of FIGURE 2; and

[0022] FIGURE 5 is a flow chart diagram of a process for forming the exemplary duct liner of FIGURE 1.

[0023] The features shown in the above referenced drawings are not intended to be drawn to scale nor are they intended to be shown in precise positional relationship. Like reference numbers indicate like elements.

DETAILED DESCRIPTION OF THE INVENTION

[0024] According to an aspect of the present invention, the substantially formaldehyde-free duct liners are formed by blending at least one fiber component with at least one non-liquid substantially formaldehyde-free binder. The formaldehyde-free binder may be plastic-containing bonding fibers or powdered binders other than phenol-formaldehyde type binders. The plastic-containing bonding fiber or other binder or their combination in the final product may be between about 10 to 30 wt. % and preferably between 12 to 25 wt. % and more preferably about 15 to 20 wt. % of the final product.

[0025] FIGURE 1 is a cross-sectional view of an exemplary substantially formaldehyde-free duct liner 10 comprising a final fiber mat 20 having a first side 21, a second side 22 and a non-woven scrim facing layer bonded to the first side 21. The final fiber mat 20 and, thus, the duct liner 10 has a density of about 16 to 56 kg/m³ and preferably about 24 to 48 kg/m³. The gram weight of the duct liner 10 is in the range of about 50 to 350 gm/m² and preferably about 65 to 310 gm/m². The thickness of the duct liner may be in the range of about 0.6 to 25.4 cm and preferably about 1.3 to 20.3 cm.

[0026] In one embodiment of the present invention, the fiber component of the substantially formaldehyde-free duct liners may comprise textile glass fibers, rotary glass fibers, organic fibers, or natural fibers such as wood fibers, hemp fibers, and cellulose fibers, etc. or a combination thereof. By employing one or more of these fibers in the formulation for the duct liners, it is possible to customize the final properties of the duct liners.

[0027] According to one preferred embodiment of the present invention, the fiber component of the substantially formaldehyde-free duct liner may be textile glass fibers. The textile glass fibers used in the duct liner product of the present invention may have diameters of greater than about 1 micrometer to 20 micrometers and more preferably about 5 micrometers up to about 16 micrometers and they are generally precut into fiber segments having average length of about 1 to 20 cm and more preferably about 2.5 to 12.5 cm.

[0028] In another embodiment of the present invention, the fiber component of the substantially formaldehyde-free duct liners may be rotary fibers. Rotary fibers are generally made by spinners using centrifugal force to extrude molten glass or polymer through small openings in the sidewall of a rotating spinner. Rotary fibers are generally smaller in diameter than textile glass fibers and may be in the range of about 2 to 5 μm . Rotary fibers have average length of up to about 12.7 cm (5 inches). The textile glass fibers and the rotary fibers may be used in combination to form the final mat 20.

[0029] In another embodiment of the present invention, the textile glass fibers and the rotary fibers described above may be used in combination for the fiber component of the formaldehyde-free duct liners. In other embodiments of the present invention, organic fibers or natural fibers such as wood fibers, hemp fibers, and cellulose fibers, etc., may be used. These fibers may be used in any combination for the fiber component of the duct liner.

[0030] The plastic-containing bonding fibers used as the binder in the substantially formaldehyde-free duct liner of the present invention may comprise thermoplastic resin, thermosetting resin, or both. The plastic-containing bonding fibers may be bi-component type polymeric fibers, mono-component type polymeric fibers, plastic-coated mineral fibers, such as, thermoplastic-coated glass fibers, or a combination thereof. The bi-component polymeric fibers are commonly classified by their fiber cross-sectional structure as side-by-side, sheath-core, islands-in-the sea and segmented-pie cross-section types. In a preferred embodiment of the present invention, the sheath-core type bi-component polymer fibers are used.

[0031] If higher strength is desired in the final product, concentric type sheath-core bi-component polymer fibers may be used. If bulkiness is desired in the final product, eccentric type sheath-core bi-component polymer fibers may be used.

[0032] The bi-component polymeric fibers have a core material covered in a sheath material that has a lower melting temperature than the core material. Both the core and the sheath material may be a thermoplastic polymer such as, for example, polyethylene, polypropylene, polyester, polyethylene terephthalate, polybutylene terephthalate, polycarbonate, polyamide, polyvinyl chloride, polyethersulfone, polyphenylene sulfide, polyimide, acrylic, fluorocarbon, polyurethane, or other thermoplastic or thermosetting polymers. The core and the sheath materials each may be made of different thermoplastic or thermosetting polymers or they may be made of the same thermoplastic or thermosetting polymers but of different formulation so that the sheath material has lower melting point than the core material. Typically, the melting point of the sheath is between about 110° and 180° Centigrade. The melting point of the core material is typically about 260° Centigrade. The bi-component polymeric fibers used in the duct liner of the present invention may have an average fiber diameter of about 10 to 20 μm and preferably about 16 μm . The average length of the bi-component plastic-containing bonding fibers is between about 0.63 to 12.7 cm and preferably between about 5.1 to 10.2 cm.

[0033] In another embodiment of the present invention, the non-liquid substantially formaldehyde-free binder may be any suitable thermoplastic powdered binder or thermosetting resin powdered binder. The powder binder may be used alone or in combination with the plastic-containing bonding fibers and blended with the fiber component of the duct liners. An example of a thermoplastic powder binder is VINNEX[®] polymer powder binders available from Wacker-Chemie GmbH. Mixing with the plastic-containing bonding fibers may be particularly beneficial when the plastic-containing bonding fibers are bi-component polymeric fibers. Because the core component of the bi-component polymeric fibers remain in fiber form to provide reinforcement to the duct liner, making the duct liner very strong for handling in the field during duct fabrication. By using a mix of the bi-component polymeric fibers and a

powder binder in varying proportions, the toughness of the duct liners can be controlled for ease of cutting.

[0034] In this exemplary embodiment of the substantially formaldehyde-free duct liner, a facing layer **30** is bonded to the first side **21** of the fiber mat **20**. In another embodiment, facing layers may be bonded to both the first side **21** and the second side **22** of the fiber mat **20** if necessary. At least one of the two sides of the duct liners will generally have a facing **30** to be designated as the air stream surface. The facing layer **30** is preferably a bonded non-woven scrim made of randomly oriented glass or resinous fibers bonded with adhesive or melt bonds. A preferred material for the non-woven scrim for this application includes glass fibers in a formaldehyde-free resinous binder. More preferred materials include a thin, bonded, non-woven fiber glass mat oriented in a random pattern, having sized glass fibers bonded with a formaldehyde-free resinous binder, preferably of the same composition of the binder used to join the fibers in mat **20**, but can also be a compatible resin.

[0035] An exemplary non-woven scrim layer may be formed from a sheet of non-woven material comprising randomly oriented inorganic fibers, and in a preferred embodiment, randomly oriented glass fibers. Non-woven materials are sheets of randomly oriented natural or synthetic fibers, such as polyolefins, polyamide (*i.e.* nylon), polyester or rayon, or glass often held in a sheet form by a binder. Binders typically used in the non-wovens are based on a polymeric material, such as an acrylic resin, a vinyl-acrylic resin, etc. To be used in the fabrication of the formaldehyde-free duct liners of the present invention, the non-woven material must also be made with formaldehyde-free binders. In an exemplary embodiment, the non-woven layer **91**, for example, is glass fiber non-wovens available from Lydall Industrial Thermal Solutions, Inc. as MANNIGLAS® 1900 or MANNIGLAS® 1908. These non-wovens are made with formaldehyde-free binders. Generally, thinner scrim materials are preferred, because they allow better penetration of the binder material that bonds the non-woven scrim **30** to fiber mat **20**.

[0036] The formaldehyde-free duct liners of the present invention is produced in accordance with air laid processing steps generally known in the art. The particular configuration of the fabrication apparatus used, however, may vary depending on the

number and the type of fibers used for the fiber components and the number and the types of formaldehyde-free binders used.

[0037] As an example, an air laid process that may be employed in fabricating duct liners according to an embodiment of the present invention will now be described. In a preferred method of forming the duct liners of the present invention, an air laid non-woven process equipment available from DOA (Dr. Otto Angleitner G.m.b.H. & Co. KG, A-4600 Wels, Daffingerstasse 10, Austria), apparatus 100 illustrated in FIGURES 2-5, may be used. In this example, a formaldehyde-free duct liner of the invention is formed by blending textile glass fibers with bi-component polymer fibers as the binder. As illustrated in FIGURE 2, the apparatus 100 includes bale openers 200 and 300, one for each type of fiber. The textile glass fibers are opened by the bale opener 200 and the bi-component polymer fibers are opened by the bale opener 300.

[0038] FIGURE 3a is a detailed illustration of the bale opener 200. The textile glass fibers are provided in bulk form as bales 60. The bales 60 are fed into the bale opener which generally comprise a coarse opener 210 and a fine opener 250. The fibers in the bales 60 may be pre-chopped or cut into segments of about 1 to 20 cm and more preferably about 2.5 to 12.5 cm long to enhance the fiber opening process. After being opened by the coarse opener 210, the textile glass fibers are weighed by an opener conveyor scale 230. The opener conveyor scale 230 monitors the amount of opened textile glass fibers being supplied to the process by continuously weighing the supply of the opened textile fibers 62 as they are being conveyed. Next, the coarsely opened textile glass fibers are finely opened by the fine opener's picker 255. The opening process fluffs up the fibers to decouple the clustered fibrous masses in the bales and enhances fiber-to-fiber separation.

[0039] FIGURE 3b is a detailed illustration of the bale opener 300. The bi-component polymer fibers are provided in bulk form as bales 70. The bales 70 are fed into the bale opener 300. The polymer fibers are first opened by a coarse opener 310 and weighed by an opener conveyor scale 330. The opener conveyor scale 330 monitors the amount of the opened plastic-containing bonding fibers being supplied to the process by continuously weighing the supply of the opened polymer fibers 72. Next, the coarsely opened polymer fibers are finely opened by the fine opener 350 and its pickers 355. For

illustrative purpose, the fine opener **350** is shown with multiple pickers **355**. The actual number and configuration of the pickers would depending on the desired degree of separation of the opened fibers into individual fibers. The bale openers **200** and **300**, including the components described above, may be provided by, for example, DOA's Bale Opener model 920/920TS.

[0040] Illustrated in FIGURE 2 is a pneumatic transport system **400** for transporting the opened fibers from the bale openers **200** and **300** to the down stream processing stations of the apparatus **100**. The pneumatic transport system **400** comprises a primary air blower **405**; a first transport conduit **410** in which the opened fibers are blended; a secondary air blower **420**; and a second transport conduit **430** for transporting the blended fibers up to the fiber condenser **500**.

[0041] FIGURE 3c illustrates opened textile glass fibers **64** and opened bi-component polymer fibers **74** being discharged into the first transport conduit **410** from their respective fine openers **250** and **350**. The airflow in the first transport conduit **410** generated by the primary air blower **405** is represented by the arrow **444**. The opened fibers **64** and **74** enters the air stream and are blended together into blended fibers **80**. The ratio of the textile glass fibers and the bi-component polymer fibers are maintained and controlled at a desired level by controlling the amount of the fibers being opened and discharged by the bale openers using the weight information from the opener conveyor scales **230** and **330**. As mentioned above, the conveyor scales **230**, **330** continuously weigh the opened fiber supply for this purpose. In this example, the fibers are blended in a given ratio to yield the final duct liner mat containing about 15 to 20 wt. % of the plastic-containing bonding fibers.

[0042] Although one opener per fiber component is illustrated in this exemplary process, the actual number of bale openers utilized in a given process may vary depending on the particular need. For example, one or more bale openers may be employed for each fiber component.

[0043] The blended fibers **80** are transported by the air stream in the pneumatic transport system **400** via the second transport conduit **430** to a fiber condenser **500**. Referring to FIGURE 4, the fiber condenser **500** condenses the blended fibers **80** into less airy fiber blend **82**. The condensing process separates air from the blend without

disrupting the uniformity (or homogeneity) of the blended fibers. The fiber blend **82** is then formed into a continuous sheet of mat **83**, which has yet to be bonded or cured depending upon whether a thermoplastic or thermosetting resin bonding agent is employed, by the feeder **550**. At this point, the mat **83** may be optionally processed through a sieve drum sheet former **600** to adjust the openness of the fibers in the mat **83**. The mat **83** is then transported by another conveyor scale **700** during which the mat **83** is continuously weighed to ensure that the flow rate of the blended fibers through the fiber condenser **500** and the sheet former **600** is at a desired rate. The conveyor scale **700** is in communication with the first set of conveyor scales **230** and **330** in the bale openers. Through this feed back loop set up, the weight of the opened fibers measured at the conveyor scales **230** and **330** are compared to the weight of the mat **83** measured at the conveyor scale **700** to determine whether the amount of the opened fibers being fed into the process at the front end matches the rate at which the mat **83** is being formed at the feeder **550**. Thus, the feed back loop set up effectively compares the feed rate of the opened fibers and the flow rate of the blended fibers through the feeder **550** and adjusts the speed of the bale openers and the rate at which the bales are being fed into the openers. This ensures that the bale openers **200** and **300** are operating at appropriate speed to meet the demand of the down stream processing. This feed back set up is used to control and adjust the feed rate of the opened fibers and the line speed of the conveyor scale **700** which are the primary variables that determine the gram weight of the mat **83**. The air laid non-woven process equipment **100** may be provided with an appropriate control system (not shown), such as a computer, that manages the operation of the equipment including the above-mentioned feed back function.

[0044] In an embodiment of the present invention that uses a formaldehyde-free powder binder rather than the plastic-containing bonding fibers, a powder binder feeder **800** may be provided to apply the powder binder **90** to the mat **83**. The powder binder feeder **800** may be positioned to apply the powder binder **90** evenly over the mat **83** as the mat is leaving the conveyor scale **700**.

[0045] A second sieve drum sheet former **850** is used to further adjust the fibers' openness and blend with powder binder (if used) before curing or heating the mat **83**. A conveyor **750** then transports the mat **83** to a curing or heating oven **900** (FIGURE 2).

For example, the condenser **500**, feeder **550**, sieve drum sheet former **600**, conveyor scale **700**, powder binder feeder **800**, and the second sieve drum sheet former **850** may be provided using DOA's Aerodynamic Sheet Forming Machine model number 1048.

[0046] In one embodiment of the present invention, a continuous web of glass fiber non-woven facing layer **91** may be dispensed from a roll **191** and is applied to at least one of the two major sides of the mat **83** before the mat **83** enters the curing or heating oven **900**. The non-woven facing layer **91** is applied to the major side of the mat **83** intended to be the air stream surface of the duct liner. In the exemplary process illustrated in FIGURE 2, the non-woven facing layer **91** is applied to the major side that is the top side of the mat **83** as it enters the curing or heating oven **900**, but depending on the particular need and preference in laying out the fabrication process, the non-woven facing layer **91** may be applied to the bottom side of the mat **83**. In another embodiment of the present invention, a non-woven facing layer may be applied to both sides of the mat **83**.

[0047] After the non-woven layer **91** is applied, the mat **83** is then fed into a curing or heating oven **900** to cure or heat the plastic-containing bonding fibers. Whether this process step is a curing step or a heating step depends on whether the binding agent used, the plastic-containing bonding fibers, is a thermoplastic type or a thermosetting type polymer. The curing or heating oven **900** is a belt-furnace type. The curing or heating temperature is generally set at a temperature that is higher than the curing or melting temperature of the binder material. In this example, the curing or heating oven **900** is set at a temperature higher than the melting point of the sheath material of the bi-component polymeric fibers but lower than the melting point of the core material of the bi-component polymeric fibers. In this example, the bi-component polymer fibers used is Celbond type 254 available from KoSa of Salisbury, North Carolina, whose sheath has a melting point of 110°C. And the curing or heating oven temperature is preferably set to be somewhat above the melting point of the sheath material at about 145°C. The sheath component will melt and bond the textile glass fibers and the remaining core of the bi-component polymeric fibers together into a final mat **88** having a substantially uniform density throughout its volume. The plastic-containing bonding fibers are in sufficient quantity in the mat **83** to bond the non-woven layer **91** to the mat. The core component

of the bi-component polymeric fibers in the final mat **88** provide reinforcement to the resulting duct liner.

[0048] In another embodiment of the present invention, the curing or heating oven **900** may be set to be at about or higher than the melting point of the core component of the bi-component polymeric fiber. This will cause the bi-component fibers to completely or almost completely melt and serve generally as a binder without necessarily providing reinforcing fibers. Because of the high fluidity of the molten plastic fibers, the glass fiber mat will be better covered and bounded. Thus, less plastic-containing bonding fibers may be used.

[0049] In another embodiment of the present invention, mono-component polymeric fibers may be used as the binder rather than the bi-component polymeric fibers. The mono-component polymeric fibers used for this purpose may be made from the same thermoplastic polymers as the bi-component polymeric fibers. The melting point of various mono-component polymeric fibers will vary and one may choose a particular mono-component polymeric fiber to meet the desired curing or heating temperature needs. Generally, the mono-component polymeric fibers will completely or almost completely melt during the curing or heating process step and bind the textile glass fibers.

[0050] In another embodiment of the present invention, a powder binder may be used rather than the plastic-containing bonding fibers. The curing or heating oven **900** will be set at a temperature appropriate to cure the powder binder. In an embodiment where the powder binder and the plastic-containing bonding fibers are used in combination, preferably the powder binder is selected to have a curing or melting temperature that matches the melting point of the plastic-containing bonding fibers to allow the fiber mat to be cured or formed into a final mat in a single pass through the curing or heating oven **900**.

[0051] After the curing or heating step, a series of finishing operations transform the final mat **88** into a duct liner. The final mat **88** exiting the curing or heating oven **900** is cooled in a cooling section (not shown) then the edges of the mat is cut to desired width. Then, the edges and the non-woven scrim are coated with water resistant epoxy foam which makes the duct liner resistant to water penetration. The coated mat is then

dried, cooled, sized into desired lengths and packaged. The duct liner and/or the facing layer may be further treated with anti-microbial agent to resist growth of fungi or bacteria.

[0052] FIGURE 5 is a flow chart diagram of the exemplary process.

[0053] At step 1000, the bales of the at least one fiber component of the duct liner are opened. If plastic-containing bonding fibers are used as the binder then the bonding fibers are also opened at this step.

[0054] At step 1010, the opened fibers are weighed continuously by one or more conveyor scales to control the amount of each fibers being supplied to the process ensuring that proper ratio of fiber(s) are blended.

[0055] At step 1020, the opened fibers are blended and transported to a fiber condenser by a pneumatic transport system which blends and transports the opened fiber(s) in an air stream through a conduit.

[0056] At step 1030, the opened fibers are condensed into more compact fiber blend and formed into a continuously feeding sheet of mat by a feeder.

[0057] At an optional step 1040, a sieve drum sheet former may be used to adjust the openness of the fiber blend in the mat.

[0058] At step 1050, the mat is continuously weighed by a conveyor scale to ensure that the flow rate of the blended fibers through the fiber condenser and the sheet former is at a desired rate. The information from this conveyor scale is fed back to the first set of conveyor scale(s) associated with the bale openers to control the bale opener(s) operation. The conveyor scales ensure that a proper supply and demand relationship is maintained between the bale opener(s) and the fiber condenser and sheet former.

[0059] At an optional step 1055, a powder binder may be applied to the mat as the continuously fed mat is leaving the conveyor scale.

[0060] At step 1060, a second sieve drum sheet former blends the powder binder (if used) into the fiber matrix of the mat and adjusts the openness of the fibers to a desired level.

[0061] At step 1070, a non-woven scrim facing may be applied to at least one side of the mat before the curing and/or heating step.

[0062] At step 1080, the mat is converted into a final mat by being cured and/or heated in a belt-furnace type curing or heating oven. The curing or heating oven is set at a temperature higher than the curing or thermosetting temperature of the particular formaldehyde-free binder being used.

[0063] At step 1090, the final mat is cooled.

[0064] At step 1092, the edges of the final mat and the non-woven scrim facing is coated with epoxy foam to provide water resistant surface to the final duct liner and cooled.

[0065] At step 1094, the coated final mat is cut to desired sizes and packaged for storage or shipping. At this step, the duct liner and/or the facing layer may be treated with anti-microbial agent to resist growth of fungi or bacteria.

[0066] According to another embodiment of the present invention, a reinforcement layer of a glass non-woven sheet may be used as a base layer for the duct liner of the present invention to provide additional mechanical support. The non-woven sheet may be applied to the mat 83 at the bottom to the mat 83 and heated or cured together. The binding action of the plastic-containing bonding fibers at the elevated temperature in the subsequent curing or heating step bonds the non-woven sheet to the mat 83.

[0067] The plastic-containing bonding fiber or other binder or their combination in the final product may be between about 10 to 30 wt. % and preferably between 12 to 25 wt. % and more preferably about 15 to 20 wt. %.

[0068] The use of the plastic-containing bonding fibers as the formaldehyde-free binder allows the duct liner fabrication process to remain dry which is simpler than using acrylic liquid binders as the formaldehyde-free binder. Also, because the curing or melting temperature for plastic-containing bonding fibers is lower than that of the conventional phenolic resin binders, the manufacturing process associated with the formaldehyde-free glass fiber duct liners consumes less energy. For example, the curing or heating ovens used in the manufacturing process described above are set to be less than about 200°C and preferably about 145°C rather than about 205° C or higher typically required for curing phenol resin binders. Also, because of the absence of formaldehyde out gassing from the binder material during the fabrication process, there is

no need for special air treatment equipment to remove formaldehyde from the curing or heating oven's exhaust. These advantages translate into lower manufacturing cost and less air pollution.

[0069] The use of the plastic-containing bonding fibers also improves the durability of the duct liner because the plastic-containing bonding fibers provide stronger adhesion between the glass fiber mat and the non-woven facing material. Furthermore, unlike the thermosetting phenolic resin binders, that are rigid and brittle when cured, the plastic-containing bonding fibers are thermoplastic polymers and are more flexible and less likely to crack and generate dust through handling. Thus, less dust is generated during the production of the duct liners as well as at the job sites where the duct liners are applied to the metal ducts.

[0070] The color of the basic duct liner mat as produced from the above-described process is generally white. The color may be easily customized by adding appropriate coloring agents, such as dyes or colored pigments.

EXAMPLE

[0071] The following non-limiting example will further illustrate the present invention.

[0072] A one inch thick sample of formaldehyde-free glass fiber duct liner made according to an embodiment of the present invention having a density of 1.5 pcf was compared to a sample of conventional glass fiber duct liner, also one inch thick and having a density of 1.5 pcf, for the following properties:

TABLE

	Formaldehyde-free Sample	Control Sample
Loss of ignition	26.1 %	29.0 %
Tensile strength (4" x 6" size):		
Cross direction	39 lbs	55 lbs
Machine direction	44 lbs	50 lbs

Thermal conductivity at 70° F	0.28 BTU in/h ft ² °F (R=36)	0.28 BTU in/h ft ² °F (R=36)
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[0073] While the foregoing invention has been described with reference to the above embodiments, various modifications and changes can be made without departing from the spirit of the invention. Accordingly, all such modifications and changes are considered to be within the scope of the appended claims.